STARFISH TRACES FROM THE NAMURIAN OF COUNTY CLARE, IRELAND

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ABSTRACT. Star-shaped trace fossils are described from the Namurian R_1 zone of the Loop Head area, West Clare. Their origin and affinities are discussed. They are compared with *Asteriacites lumbricalis* Schl., a Lias fossil, and interpreted as Ophiuroid resting-traces. They are considered to contribute to the interpretation of the environment of deposition of the rock sequence in which they occur.

THE star-shaped trace fossils which form the subject of this paper were collected from Namurian sandstones exposed on the northern shore of the Shannon Estuary at Doonaha House, half a mile south-south-west of the village of Doonaha near Carrigaholt, Loop Head peninsula, Co. Clare. At this locality, the succession consists of a considerable thickness of unfossiliferous micaceous sandstones, siltstones, and silty shales. The trace fossils were scattered over one particular bedding-plane forming a 'starfish bed'. The nearest black shale band with a goniatite fauna underlies the barren series at Kilcredaun Point, some three miles to the west along the strike. Here the fossiliferous beds contain *Reticuloceras paucicrenulatum* Bisat and Hudson, *R. circumplicatile* (Foord), and related reticuloceratids, indicating a Kinderscoutian (R_1) age for the succeeding strata. The actual thickness of barren beds between the 'starfish bed' and the proven R_1 shales is almost impossible to estimate accurately, due to extensive penecontemporaneous slumping of the strata, but it is of the order of 1,500 feet. The stratigraphy of the Loop Head area will be described in a later paper.

The sandstone sequence at Doonaha forms, therefore, the homotaxial equivalent of part of the Clare Shales succession of the east crop of the Clare–Limerick Namurian Basin (Hodson and Lewarne 1961). The trace fossils have been found, as yet, in the one locality only. They are interesting as facies indicators of a series of strata in which no other organic remains have been found.

DESCRIPTION

The slab of rock from the starfish bed on which the illustrations were based represents the lower surface of a flag of micaceous siltstone reflecting in relief the negative features of the top surface of the bed below (text-fig. 1). There are two main kinds of impression: (*a*) striation groove-casts orientated in a predominantly NW/SE direction, and (*b*) randomly scattered star-shaped casts similar to the 'Sternspuren' of Seilacher (1953). There are also various irregularities and scattered 'dots' representing the pitted surface of the original substratum.

The star-traces are surface features only, as can be ascertained from an examination of the underlying bed of rock on which they were formed as depressions. They are consistently five-armed, the arms being about 5 mm. long and radiating out from a central 'hub' which appears as a slight elevation on the cast (text-fig. 2*a*, *b*). Occasionally there is duplication of one of the arms (text-fig. 2*c*), or it may appear forked (text-fig. 2*d*).

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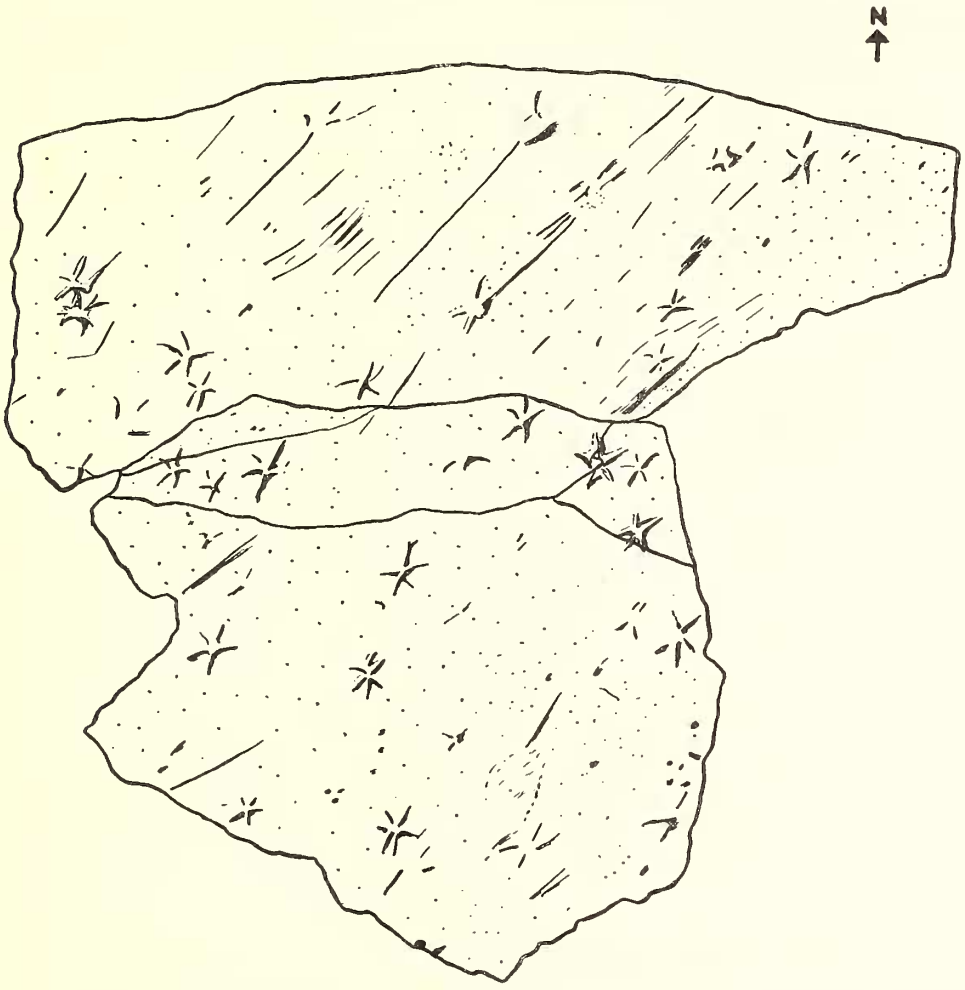
Sometimes two or more impressions cut across each other with some lateral displacement. Assuming that the traces were made by animals, the superimposed impressions could have been produced by two separate individuals or by the same individual at different



TEXT-FIG. 1. Starfish traces from the Namurian of Doonaha, Co. Clare. Underside of cracked slab of sandstone in the collection of the Geology Department, Trinity College, Dublin, specimens TCD 3599 and TCD 3600. $\times\frac{3}{5}$.

times. Sometimes the star shapes of superimposed traces can hardly be distinguished, and they form an irregularly shaped cast (text-fig. 2*f*). This would represent a corresponding 'flurry' depression on the original sea-floor made by settling movements of the animal, or possibly by its agitation due to a disturbing influence.

The star-traces have no ornament except for occasional cross-striation of the arms (text-fig. 2*b*). Except for the superimposition described above, there is no regular pattern or relationship between the individual star-traces which are randomly scattered

across the bedding plane of the rock. They are, therefore, traces of an agency which settled at intervals upon the substratum, and not of a walking or crawling animal.

The star-traces obliterate the striation-casts and sometimes terminate them (text-fig. 2*e*, *f*). They must, therefore, have been produced by some agent capable of (*a*) superseding the striation-casts and (*b*) acting as a barrier to the continuing formation of the striations. An obvious agent would be the body of some animal which rested intermittently on the substratum, burying itself slightly as it did so, and thus interrupting the sedimentation pattern already established by currents sweeping the sea-floor.

DISCUSSION

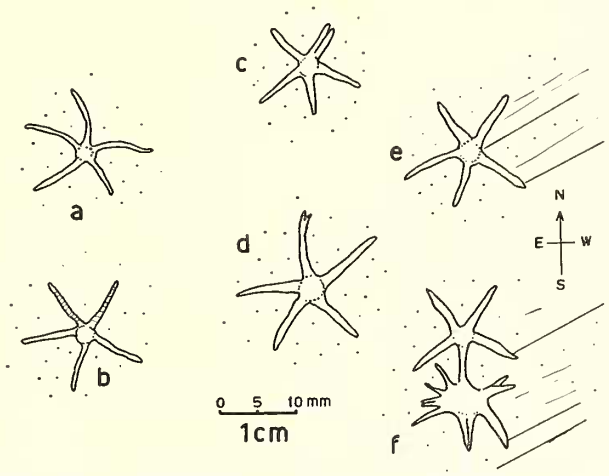
Star-shaped trace fossils have been described from many horizons and localities, and have been attributed to the activity of several groups of animals.

Certain sand-crabs and other crustaceans burrow into the sand as a protective measure, or during the intertidal period (Green 1961, chap. 2). Some tropical crabs while searching for food make scoop-marks in the sand surrounding the entrance to their burrows, which they form into piles of small balls. The furrows often form an irregular star-shaped pattern (Abel 1935, p. 388 and figs. 322–3; Lessertisseur 1955, p. 30). The amphipod *Corophium*, a mud-grazer found in temperate climatic regions (Yonge 1949, p. 30) also makes star-shaped feeding-traces (Abel 1935, p. 389, fig. 325). Certain authors such as Abel (1935, p. 390) claim that crustacean star-traces can be distinguished from those made by burrowing worms by several characteristics. Crustacean traces are said to have furrows of equal length radiating out from a central knob; sometimes a wall of debris is produced near the trace. Traces made by burrowing worms are distinguished by the absence of a central knob and by their ramifying furrows of unequal length. These criteria ought, however, as pointed out by Lessertisseur (1955, p. 53) to be used with discretion as they do not seem to be universally applicable. Indeed, Abel figures crab traces (1935, fig. 324) with furrows of unequal length, and *Corophium* traces (op. cit. fig. 325) with branched furrows.

The star-traces produced by burrowing worms are caused by the sweeping movements of the animal's tentacles around the aperture of its burrow (Lessertisseur 1955, p. 53). Certain burrowing lamellibranchs such as *Scrobicularia* (ibid., p. 27, fig. 13*a*, *b*) and *Mactra* (ibid., pl. ii, fig. 11) also produce irregular star-shaped furrows round the entrance to the respiratory channels of their burrows.

None of these traces, however, resemble those from Doonaha, which are, except in readily explained instances, regularly five-branched, the branches radiating from a central 'hub'. This pentameral symmetry strongly indicates an Echinoderm origin, and the form of the traces suggests that they are the resting places of a Stelleroid, either an Asteroid or an Ophiuroid. Observation of shore-dwelling Stelleroids, e.g. *Astropecten irregularis* (Yonge 1949, p. 237) and experimental evidence (Seilacher 1953*a*, Abb. 1, Taf. 7 and 11) show that certain members of this group tend to bury themselves shallowly when at rest. The absence of any disturbance of the sedimentation immediately underneath the negative star-traces on the upper surface of the underlying bed of the Doonaha specimens precludes any more deeply burrowing animal such as a lamellibranch, worm, or shore-crab, a conclusion which is substantiated by the absence of any sign of an included fauna.

Traces attributed to Stelleroids have been reported from various horizons. A resumé of these references and a detailed interpretation of the mode of formation of these traces have been published by Seilacher (1953*a*). Seilacher showed how Ophiuroids can produce star-shaped resting-traces with broad Asteroid-like arms (op. cit., p. 98 and Abb. 2: 1*a*, *b*, 2*a*, *b*) which may appear forked due to movement of the animal (ibid., 3*a*, *b*). He also showed that superimposed impressions can be produced by successive



TEXT-FIG. 2. Starfish traces from the Namurian of Doonaha, Co. Clare. Individual specimens from the slab illustrated in Text-fig. 1. Note in (*a*) form of star-trace, (*b*) cross-striations, (*c*) bifurcation, and (*d*) forking due to movement of one arm, (*e*) and (*f*) inter-relationship of star-traces and striation casts, and (*f*) effect of movement and re-settling. All figures × 1.

settling of the animal into nearly the same place (op. cit., Taf. 8, fig. 2, and p. 100, Abb. 3).

As one of several examples of fossil Ophiuroid resting-traces, Seilacher figured (op. cit., Taf. 7, fig. 2) a small sculptureless variety of star-trace from the Liassic *Schlotheimia angulata* sandstone of Hüttlingen near Aalen. These were originally described by Quenstedt as impressions similar to starfish and serpent-stars (Seilacher 1953*a*, p. 95). Each star-trace is about 10–12 mm. in diameter. They are almost identical with the Carboniferous trace fossils from Doonaha, the latter having slightly more slender arms (text-fig. 1). On the slab figured by Seilacher one can see examples of superimposition of two traces made by the same animal, as well as duplication or forking of individual arm impressions, interpreted as movement and resettling. These features have also been seen in the Doonaha specimens (text-fig. 2*c*, *d*, *f*).

Seilacher referred the Hüttlingen specimens to *Asteriacites lumbricalis* Schlotheim. He redefined the genus and species as follows (1953*a*, p. 101):

Asteriacites: Normalerweise 5strahliger Stern.

A. lumbricalis Schl.: Relativ klein und schlank, besonders in großen Exemplaren.

Since the Doonaha traces correspond to this definition they must have been produced by animals of the same size and form as those which produced the Lias star-traces

figured by Seilacher. These animals might have been Asteroids but following Seilacher's experimental evidence the greater possibility seems to be that they were Ophiuroids. It is suggested that some of the 'dot-marks' corresponding to pits on the substratum might be traces left by the arm-tips of the animals as they moved freely about.

Carboniferous asteriaform fossils were described from the Francis Formation (Pennsylvanian) of Oklahoma by Jones (1935). The fossils occurred in a thin sandstone with a varied marine fauna (op. cit., p. 247). In size and shape they correspond closely with the Doonaha star-traces (op. cit., fig. 1). Jones interpreted the traces as young starfish, with the reservation that they might be plant remains.

This occurrence of Ophiuroid resting-traces in the Upper Carboniferous of Co. Clare is of some interest, as they were found in the midst of an otherwise barren sequence of fine-grained unsorted micaceous sandstones and siltstones. The absence of a shelly fauna rules out the littoral zone as an environment of sedimentation, though the occurrence of oscillation ripple marks in certain beds shows that some at least of the sandstones were laid down above wave-base. The presence of the striation-casts shows that the sea-floor was swept by gentle currents. The NW–SE orientation of the casts is remarkably constant and may well be connected with the predominantly east–westerly orientation of ripple marks in lower horizons.

The fact that the striation-casts are in several cases obliterated by the star-traces seems to indicate that the animals producing the latter settled themselves well into the bottom sediment each time they came to rest. This corresponds to Seilacher's observations on the behaviour of living Ophiuroids (1953*a*, p. 94, Abb. 1*b*). In some cases the striation-casts approach the star-traces from the north-west and terminate against them; this suggests that the animals were already in position when currents bringing sediment from the north-west caused striation-grooves to be formed. This would confirm the interpretation of the star-traces as depressions made by a resting Stelleroid whose body would make a barrier to the formation of grooves rather than as empty scoop-marks such as could have been made by other groups of animals. The regular pentameral shape and evidence of movement would make the formation of the hollows by an algal colony or holdfast seem extremely unlikely.

It is known that while Ophiuroids are not uncommon in the shallowest water of the littoral zone, they are most numerous in a considerable depth of water and even beyond the shelf zone. An underwater photograph of the Atlantic continental slope south of Cape Cod, Mass., U.S.A., at a depth of 6,000 feet is reproduced by Seilacher (1953*b*, Taf. 7, Bild 7) and by Leet and Judson (1958, figs. 14–12). This photograph shows several brittle-stars on the sea-floor. However the presence of blunt-crested oscillation ripple-marks in strata above and below the bed containing the Doonaha starfish traces indicates that they were laid down in the shallower water of the continental shelf. Jones (1935, p. 428) recorded that the Oklahoma Pennsylvanian star-traces were associated with worm burrows and wave ripple-marks and concluded that the sediment was deposited in shallow water. The Lias sandstone slab figured by Seilacher (1953*a*, Taf. 7, fig. 2) also appears to be ripple-marked.

The Doonaha Starfish Bed occurs in the undisturbed strata succeeding a succession of sheet slumps similar to those described from other parts of West Clare by Gill (Gill and Kuenen 1957). Sand volcanoes are sometimes associated with the slumps, as at the shore near Liscrona House. These slumped sandstones with their superimposed sand

volcanoes would be interpreted by Gill and Kuenen as being due to subaqueous sliding down an original slope, initiated by seismic shaking, and with subsequent extrusion of included water from the slumped sediment (op. cit., p. 455).

The sum total of these characteristics of the sediment-slumps, sand volcanoes, ripple marks, and starfish traces—indicates that the rock sequence in question was laid down in a shelf environment with an initial depositional slope, and in a moderate depth of water which never greatly exceeded wave-base. The last phase of deeper water with euxinic bottom conditions extant is now represented by the goniatitic shales of Kilcredaun with their pelagic fauna.

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